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Interaction of Birth Order, Handedness, and Sexual Orientation in the Kinsey Interview Data

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Recent evidence indicates that 2 of the most consistently observed correlates of men's sexual orientation—handedness and older brothers—may be linked interactively in their prediction of men's sexual orientation. In this article, the authors studied the relationship among handedness, older brothers, and men's sexual orientation in the large and historically significant database originally compiled by Alfred C. Kinsey and his colleagues (A. C. Kinsey, W. B. Pomeroy, & C. E. Martin, 1948). The results demonstrated that handedness moderates the relationship between older brothers and sexual orientation. Specifically, older brothers increased the odds of homosexuality in right-handers only; in non-right-handers, older brothers did not affect the odds of homosexuality. These results refine the possible biological explanations reported to underlie both the handedness and older brother relationships to men's sexual orientation. These results also suggest that biological explanations of men's sexual orientation are likely relevant across time, as the Kinsey data comprise an older cohort relative to modern samples.

Keywords: sexual orientation, older brothers, birth order, handedness, Kinsey

A body of research indicates that sexual orientation may have a biological (e.g., prenatal) origin (e.g., Wilson & Rahman, 2005). Studies showing that brain anatomy and functioning are correlated with sexual orientation support this view (e.g., LeVay, 1991; McFadden & Champlin, 2000; Swaab & Hofman, 1990). For example, homosexual and heterosexual men differ in the size and structure of the third interstitial nucleus of the anterior hypothalamus (Byne et al., 2001; LeVay, 1991). This site is also known to be sexually dimorphic (Allen, Hines, Shryne, & Gorski, 1989; Byne et al., 2001; LeVay, 1991), and animal studies suggest that this region is very important in male-oriented sexual behavior (Grady, Phoenix, & Young, 1965; Rhees, Shryne, & Gorski, 1990). This research supports the theory that human sexual orientation is influenced by prenatal hormones (e.g., testosterone), which have organizing effects on the fetal brain during sexual differentiation (e.g., Ellis & Ames, 1987). In addition, genetic studies also favor a biological origin for sexual orientation. Sexual

orientation is partly heritable (e.g., Bailey, Dunne, & Martin, 2000), and studies using molecular genetic techniques have indicated that a region on the X chromosome (Xq28) may be associated with male homosexuality (Hamer, Hu, Magnusson, Hu, & Pattatucci, 1993; Hu et al. 1995; but see Rice, Anderson, Risch, & Ebers, 1999). Recently, researchers have also found evidence that sites on the autosomes may be linked to male sexual orientation (Mustanski et al., 2005).

Studies examining markers of early neurodevelopment, such as handedness (Lalumière, Blanchard, & Zucker, 2000) also support a biological basis of sexual orientation. Hand preference is an important variable within the context of a potential biological (e.g., prenatal) basis of sexual orientation because it is very likely determined early in life and is not usually amenable to large changes after birth. For example, it can be observed prenatally using ultrasound imaging (Hepper, Shahidullah, & White, 1991; Hepper, Wells, & Lynch, 2005). Handedness has also been linked to genes (e.g., Medland et al., 2005), and it has been theorized to relate to prenatal conditions, including prenatal hormones (e.g., Witelson, 1991). In addition, handedness is correlated with characteristics of early neurodevelopment, such as cerebral laterality (e.g., Bryden & Steenhuis, 1991), fluctuating asymmetry (e.g., Yeo, Gangestad, & Daniel, 1993), and some neurodevelopmental problems (e.g., Coren, 1993; Previc, 1996). There is also some evidence that handedness may be linked to cognitive (e.g., spatial) abilities (e.g., Peters, Reimers, & Manning, 2006) and that these abilities may also have an early developmental origin (e.g., Hampson, Rovet, & Altman, 1998). Thus, demonstrating a reliable relationship between handedness and sexual orientation is important for a possible biological (e.g., prenatal) origin of sexual orientation because handedness is a marker of early neurodevel-

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opment. It is also notable that many of the correlates of handedness (e.g., cerebral laterality, prenatal hormonal profiles, spatial ability) have been linked empirically and/or theoretically to sexual orientation (e.g., Alexander & Sufka, 1993; Ellis & Ames, 1987; McCormick & Witelson, 1991, respectively). Thus, handedness, relative to other markers of early neurodevelopment, is a good candidate to be studied within the context of sexual-orientation development.

Using a meta-analysis of existing studies, Lalumière et al. (2000) established that a reliable relationship does exist between handedness and sexual orientation. Homosexual men and women were found to have 39% greater odds of being non-right-handed relative to their heterosexual counterparts. Prior to this meta-analysis, the literature seemed conflicted, particularly in men; a number of large-scale studies did not show an elevated non-right-handedness in homosexual men (e.g., Bogaert & Blanchard, 1996). Lalumière et al. (2000) reviewed a number of theories (e.g., prenatal hormonal, immunological) to explain why homosexual men and women have elevated non-right-handedness, although they argued the most plausible explanation is because some homosexual men and women may have experienced early developmental instability, which shifts early brain development away from both right-handedness and heterosexuality. Recently, others have argued that genetic factors may best explain this relationship (e.g., Hatfield, 2006).

Another correlate of sexual orientation in men is number of older brothers (or fraternal birth order; FBO). This was first established by Blanchard and Bogaert (1996a, 1996b) but has been replicated since then by these researchers and others numerous times (for a review, see Blanchard, 2004). There is no evidence of a birth-order effect in women (e.g., Bogaert, 1997). The most well-articulated biological explanation of the FBO effect involves a maternal immune response, in which a mother produces an immune response (e.g., antibodies) to a factor (or to factors) in male development over succeeding male pregnancies (Blanchard & Bogaert, 1996a; Blanchard & Klassen, 1997). Factors involved with female development would not be the target of a mother's potential immune response because she herself is female. This immune effect is hypothesized to cause an alteration in (some) later born males' prenatal brain development. Blanchard (2004) argued that the target of the immune response may be male-specific molecules on the surface of male fetal brain cells (e.g., including those in the anterior hypothalamus). Antimale antibodies might bind to these molecules and thus interfere with their role in normal sexual differentiation, leading some later born males to being attracted to men as opposed to women. There is no direct support for the immune hypothesis, but various lines of evidence are in its favor (see Blanchard, 2004; Blanchard & Klassen, 1997; cf., Whitehead, *in press*), including recent evidence that the FBO effect is very likely prenatal in origin (Bogaert, 2006).

Handedness and FBO have also been recently shown to be linked interactively in their relation to men's sexual orientation (Blanchard, Cantor, Bogaert, Breedlove, & Ellis, 2006). Blanchard et al. (2006) demonstrated that older brothers increased the odds of homosexuality in right-handers only; in non-right-handers, older brothers either did not affect or decreased the odds of homosexuality. In addition, elevated non-right-handedness was restricted to gay men with no older brothers; an increased level of right-handedness occurred in gay men with one or more older brothers.

These results are important in at least two ways. First, it gives additional evidence that the FBO effect has a prenatal origin because of its linkage to this important marker of prenatal development. Second, these results are important because they refine the possible biological explanations reported to underlie both the handedness and older brother relationships to men's sexual orientation.

New evidence has been marshaled in support of the reliability of this interaction (Blanchard & Lippa, 2007; Blanchard & Lippa, *in press*; Bogaert, 2007). For example, Blanchard and Lippa (*in press*) found evidence for this interaction after using a different methodological and statistical approach than did Blanchard et al. (2006), who used a logistic regression and compared empirical groups (i.e., homosexual vs. heterosexual) with each other to demonstrate this interaction. Blanchard and Lippa (*in press-b*) compared sibling characteristics of various groups (i.e., non-right-handed homosexual men, right-handed homosexual men, non-right-handed heterosexual men, right-handed heterosexual men) against the highly stable human sex ratio (i.e., the ratio of male live births to female live births). In human populations, the ratio of male live births to female live births is close to 106:100 (Chahnazarian, 1988; James, 1987). If older brothers are elevated in right-handed homosexual men only, then the sibling sex ratio for older siblings (i.e., older brothers to older sisters) should also be elevated in right-handed homosexual men only. This is precisely what Blanchard and Lippa (*in press*) found: Right-handed homosexual men had an elevated number of older brothers to older sisters (125) relative to the known human sex ratio (106). In contrast, non-right-handed homosexual men had a lower than expected number of older brothers to older sisters (83) relative to the known human sex ratio (106). These results support Blanchard et al.'s (2006) original finding of an interaction between handedness and older brothers and that a higher number of older brothers is associated with homosexuality in right-handers only. However, these supportive results (see also Bogaert, 2007) are partially in contrast to one very large study (Blanchard & Lippa, 2007), which recently provided only qualified support for this Handedness $\times$ Older Brother interaction.

The original Kinsey data (Kinsey et al., 1948; cf., Gebhard & Johnson, 1979) represents a unique opportunity to continue to investigate handedness, older brothers, and sexual orientation. This sample is large and provides a potentially powerful test of interactions that are often difficult to detect (or replicate once detected). In addition, demonstrating any handedness effect—even if it is a conditional one—is important because the Kinsey data are from a different era (1930s–1960s) than all modern samples showing evidence of a relationship between handedness and sexual orientation. Indeed, many of the participants interviewed by Kinsey and his colleagues were born prior to 1900. The Kinsey data, then, represent a rare opportunity to investigate these issues in men who are three or more generations removed from many modern samples. Thus, it could provide evidence of generalizability of a handedness effect and, by implication, evidence of a consistent prenatal influence on sexual orientation across time. It is of note that FBO is the only correlate of men's sexual orientation with a strong tie to prenatal influences that is shown to have this level of generalizability (including correlates found in the original Kinsey data; Blanchard & Bogaert, 1996a). Finally, the original Kinsey data, because of its historical significance and large sample size,

represented a salient failure to replicate the relationship between handedness and sexual orientation in men (Bogaert & Blanchard, 1996). Demonstrating that a handedness effect is indeed detectable in these data (as part of a Handedness $\times$ FBO interaction) may then indicate why handedness has been an inconsistent correlate of men's sexual orientation (cf., Lalumière et al., 2000). It would suggest that the relationship between handedness and sexual orientation in men is often not observable as a strong main effect but only as one conditionally linked to the number of older brothers. Thus, it would support the hypothesis that there is a reliable relationship between handedness and sexual orientation but that this effect should be considered within the context of an interaction with older brothers.

Method

Participants

A total of 17,502 case histories taken from 1938 to 1963 are included in the computerized databases of The Kinsey Institute for Research in Sex, Gender, and Reproduction. We restricted the sample to those males 18 years or older who had no convictions for felonies or misdemeanors and who had not resided in a foster home or orphanage during childhood. Men with criminal histories were excluded because they might have spent time in jail (whether ultimately convicted or not) and thus may have had homosexual experiences that did not reflect their basic orientation. Men who lived in foster homes or orphanages were excluded because they might not be able to report accurately on their sibship composition in comparison with those who had intact families. Note that Blanchard and Bogaert (1996a) used these exclusion criteria as well. There were 5,774 men who satisfied these criteria.

Handedness

Hand preference was assessed by the question, "Are you right or left handed?". Four responses were recorded: right-handed ($n = 4,106$), left-handed ($n = 329$), ambidextrous ($n = 167$), and right-handed, retrained from left-handed ($n = 27$) (Gebhard & Johnson, 1979). The latter three categories were collapsed into non-right-handed ($n = 523$). Note that missing data occurred in 1,145 men.

Sibling Characteristics and Additional Demographics

Information on sibling characteristics (e.g., number of older brothers, number of older sisters) was collected by the Kinsey interviewers, but all sibling numbers over 8 were collapsed into one category (8+). Twins were not counted in these totals, but deceased siblings were. There was no way to separate biological (full or half) siblings from nonbiological siblings (e.g., stepsiblings). Finally, age in years and education (grades completed) were also assessed in this study.

Sexual Orientation

Consistent with our previous research using the Kinsey data (e.g., Blanchard & Bogaert, 1996a; Bogaert & Blanchard, 1996), men were classified as homosexual or heterosexual using two criteria: amount of homosexual experience and homosexual

arousal. Men who reported extensive homosexual experience, defined by Gebhard and Johnson (1979) as more than 20 male sexual partners or more than 50 homosexual experiences (with one or more partners), were classified as homosexual. Men were classified as heterosexual if they reported either no or rare homosexual experiences, the latter defined by Gebhard and Johnson (1979) as one male sexual partner and/or one to five homosexual experiences. In addition, heterosexual men had to report that they did not experience much or some sexual arousal from thinking or seeing other males. Using these criteria (and having nonmissing data on handedness), we classified 730 homosexual men and 3,225 heterosexual men.

Results

The mean age of the 3,225 heterosexual participants was 29.60 years ($SD = 11.06$) and that of the 730 homosexual participants was 30.79 years ($SD = 10.40$). The age difference was obviously quite small in absolute terms, but it was statistically significant because of the large sample size, $t(3,953) = -2.66$, $p = .008$. (All p values reported in this paper are two-tailed unless otherwise noted.) One heterosexual participant lacked data on educational achievement (number of grades completed). The mean education of the remainder was 16.14 grades ($SD = 3.17$) and that of the homosexual participants was 14.73 grades ($SD = 3.45$). This difference was also statistically significant, $t(3,952) = 10.68$, $p < .001$. Despite these differences, the main logistic regression analysis testing for a Handedness $\times$ Older Brother interaction did not change appreciably when age and education were controlled, so these variables were not included in the presentation of the results.

There were 646 homosexual and 2,868 heterosexual right-handers, and 84 homosexual and 357 heterosexual non-right-handers. Figure 1 shows the percentage of participants who were homosexual, plotted as a function of their hand preference and their number of older brothers. The figure shows the usual association between increasing numbers of older brothers and increasing probabilities of homosexuality, but only for right-handed men. For non-right-handed men, the curve relating older brothers to homosexuality appears quite different, perhaps even opposite. It should be noted that the capping of the older brothers variable at "three or more" was done solely for the purpose of tidying the graphical display. In all statistical analyses, numbers of older brothers (and older sisters) were analyzed exactly as reported.

Analogous data are shown in Figure 2 for number of older sisters. There is, again as usual, little evidence of any association between a man's number of older sisters and his likelihood of homosexuality. The curve for right-handers is virtually flat, and the curve for non-right-handers shows no discernable trend.

The data in Figure 1 (which resemble those in Figure 1 of Blanchard et al., 2006) suggest an interaction between older brothers and handedness with regard to sexual orientation. This was investigated in a series of logistic regression analyses. All these analyses used the same criterion variable—sexual orientation—which was dichotomously coded as 0 (*heterosexual*) or 1 (*homosexual*).

The first logistic regression analysis investigated whether regression lines fitted to the data shown in the figure would in fact differ significantly in slope between right-handed and non-right-handed men. This analysis was carried out on all 3,955 partici-

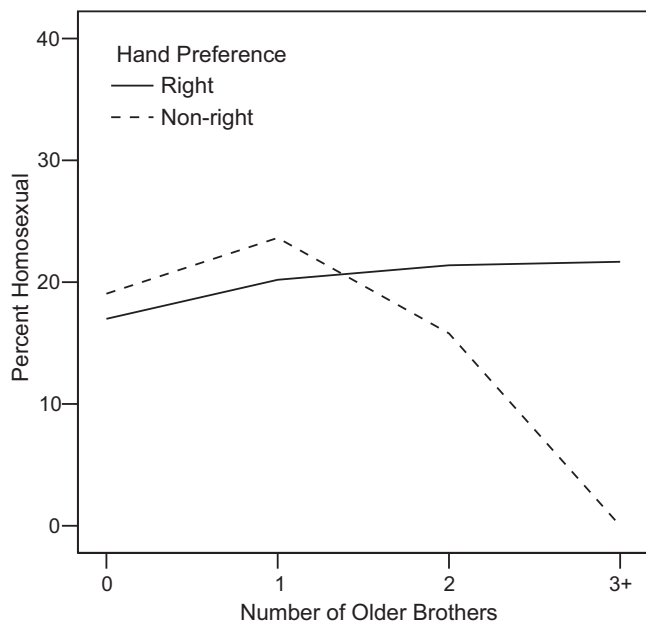


Figure 1. Percentage of participants who were homosexual, plotted as a function of older brothers and handedness.

pants. There were three predictor variables. The first was the participant's number of older brothers, which was treated as a continuous variable. The second was hand preference, which was treated as a categorical variable. This variable was deviation coded -1 (right-handed) or $+1$ (non-right-handed). The third predictor was the product of handedness and older brothers, which carried the interaction of these variables. Table 1 shows the results with all predictors in the model.

In Table 1 (and similarly in Tables 2–4), each coefficient (B) represents the change in the log odds of homosexuality for a one-unit increase in the corresponding predictor, controlling for all other predictors in the model. The next column presents the standard error for each B . The Wald statistic and its associated degrees of freedom were used to determine the p value of each predictor variable. The quantity (e^B) is the multiplicative change in the odds of homosexuality for a one-unit increase in the corresponding predictor, and thus $100 \times (e^B - 1)$ represents the percentage change in the odds for a one-unit increase in that predictor.

Main effects in logistic regression are generally not interpreted with their interaction terms in the model, and our conclusions regarding older brothers per se are taken from other analyses presented shortly. The single important result from Table 1, therefore, is that there was a statistically significant interaction between number of older brothers and handedness. As shown in the table, the p value based on the Wald statistic was .04. Estimating p from the Wald statistic, however, can be less accurate than estimating p from another statistic, namely, the change in $-2 \log$ likelihood when a variable (in this case, the interaction term) is added to or removed from the model containing the other predictors. The latter method yielded a slightly lower probability for the Handedness $\times$ Older Brothers interaction, $\chi^2(1, N = 3,955) = 4.67, p = .03$. Thus, both methods led to the conclusion that older brothers have different effects on right-handed and non-right-handed males.

Table 1 shows that the main effect for older brothers was not significant when the full group of participants was used and when the handedness and the Handedness $\times$ Older brothers terms were included in the model. The second and third analyses tested whether the relations between older brothers and sexual orientation (see Figure 1) would be statistically significant within groups who shared the same hand preference.

The second analysis was carried out on the 3,514 right-handers only. The sole predictor was the participant's number of older brothers. The results (top row of entries in Table 2) yielded a significant odds ratio of 1.11 for older brothers, which means that each older brother increased the odds of homosexuality by about 11%. It must be stressed that this result cannot be considered a replication because the sample includes previously published data (e.g., Blanchard & Bogaert, 1996a). The magnitude of the odds ratio (1.11) was smaller than usual (e.g., Blanchard & Bogaert, 1996b).

The third analysis was similar to the second one except that it was carried out on the 441 non-right-handers only. The results are the bottom row of entries in Table 2. Among non-right-handers, older brothers lowered rather than raised the odds of homosexuality, but the relation was not statistically significant.

In summary, we could reject the hypothesis that the slope of the line relating older brothers to sexual orientation is zero for right-handed participants, and we could reject the hypothesis that the slope is the same for right-handed and non-right-handed participants. We could not reject the hypothesis that the slope is zero for the non-right-handed participants, despite the negative-tending curve suggested by Figure 1.

We conducted a similar set of logistic regression analyses, substituting older sisters for older brothers. The results are shown in Tables 3 and 4. None of the examined relations even approached statistical significance.

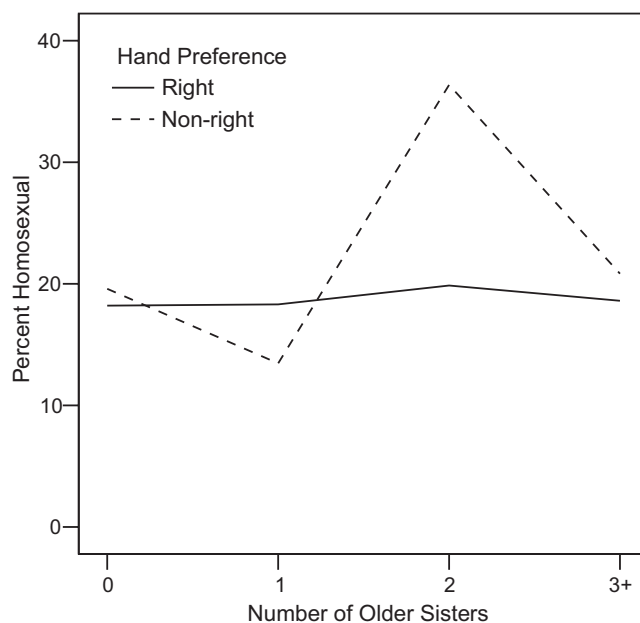


Figure 2. Percentage of participants who were homosexual, plotted as a function of older sisters and handedness.

Table 1
Logistic Regression of Sexual Orientation on Number of Older Brothers and Hand Preference for All Participants

Predictor	<i>B</i>	<i>SE</i>	Wald statistic	<i>df</i>	<i>p</i>	<i>e^B</i>
Older brothers	−0.06	0.08	0.53	1	.47	0.95
Handedness	0.11	0.08	2.22	1	.14	1.12
Handedness × Older Brothers	−0.16	0.08	4.10	1	.04	0.85

The foregoing analyses involved comparing empirical groups with each other. Additional information about the relations among handedness, sexual orientation, and older brothers was sought by comparing each of these groups with the well-established and highly stable human sex ratio, which, as mentioned, approximates 106 male live births to 100 female births (Chahnazarian, 1988; James, 1987).

Table 5 shows the data of interest: the sibling sex ratio for each group. The sibling sex ratio is usually calculated as the ratio of brothers to sisters collectively reported by a given group of persons. In the present study (as in Blanchard & Lippa, in press, and Williams et al., 2000), it was calculated as the ratio of older brothers to older sisters. The ratio of older brothers to older sisters reported by any group of persons drawn at random from the general population should, like the ratio of brothers to sisters, approach 106 older brothers per 100 older sisters.

The reporting of siblings' sex ratio as the ratio of brothers per 100 sisters is traditional; for the computation of inferential statistics, however, this value is more conveniently expressed as the proportion of brothers rather than the ratio of brothers to sisters (i.e., .515; $106 \div 206$). The sibling sex ratios presented in Table 5 (converted into proportions) were compared with the general population value (.515) using the *z* approximation to the binomial test.

We predicted, on the basis of much prior research (e.g., Blanchard, 2004, Figure 2), that the sibling sex ratio of the right-handed homosexual men would be higher than 106. We further predicted, on the basis of the findings of Blanchard et al. (2006) and Blanchard and Lippa (in press), that the sibling sex ratio of the non-right-handed homosexual men would be lower than 106. There was no prior empirical or theoretical basis for any directional hypothesis regarding the sibling sex ratio of the non-right-handed heterosexual men, and the sibling sex ratio of the right-handed heterosexual men was expected not to differ from the expected ratio of 106. Rather than report one-tailed tests for the homosexual groups and two-tailed tests for the heterosexual groups, we have simply reported one-tailed tests for all groups.

The observed ratio of older brothers to older sisters was 127 for the right-handed homosexual men. This is significantly higher than

the expected value of 106 and thus confirmed our prediction. This finding should not be regarded as a replication, because older sibling sex ratio data from these participants have been reported before (e.g., Blanchard, 2004). The sibling sex ratio for the non-right-handed homosexual men was 81, which is similar in magnitude to the ratio of 83 observed by Blanchard and Lippa (in press). The present finding is not significantly different from the expected value of 106, however. The sibling sex ratios of the heterosexual groups did not differ from the expected value, despite substantial sample sizes.

Discussion

The results indicated that handedness and older brothers (FBO) are linked interactively in their prediction of men's sexual orientation. This was shown by comparing empirical groups with each other but also by the analysis of sibling sex ratio. Older brothers increased the odds of homosexuality in right-handers only; in non-right-handers, older brothers did not affect the odds of being homosexual. These results support recent studies (Blanchard et al., 2006; Blanchard & Lippa, in press; Bogaert, 2007; cf., Blanchard & Lippa, 2007) and indicate that this Handedness × FBO interaction is a reliable finding. It is notable that the magnitude of the odds ratio that we obtained from the main logistic regression for the Handedness × Older Brothers interaction (0.85) in the present study was very similar to the estimate of 0.83 obtained by Blanchard et al. (2006, Table 2).

Given that handedness is an important marker of prenatal development, these findings support the notion that men's sexual orientation is affected by prenatal events. The findings also provide additional evidence that the FBO effect is of prenatal origin because of its apparent linkage to this important marker of prenatal development (see also Bogaert, 2006). These results also suggest that prenatal events are consistently affecting men's sexual orientation across different historical eras of the 20th century. The present handedness effect, moderated by older brothers, was demonstrated in a sample primarily collected during the 1930s and 1940s (see Gebhard & Johnson, 1979; Kinsey et al., 1948), in contrast to the handedness effects demonstrated in the remainder of the samples, which were collected in the modern era (see Lalumière et al., 2000). Thus, the (prenatal) effect on sexual orientation is not idiosyncratic to one generation in the modern era, but is likely an enduring one that cuts across a number of generations of men.

This interaction also necessarily refines the explanations reported to underlie both the handedness and FBO effects on men's sexual orientation. Two of these explanations are genetic in origin. Genes may predispose a family to atypical (e.g., nonright) handedness and also confer resistance to a maternal immune response

Table 2
Logistic Regression of Sexual Orientation on Number of Older Brothers, With Separate Analyses for Right-Handed and Non-Right-Handed Participants

Participants	<i>B</i>	<i>SE</i>	Wald statistic	<i>df</i>	<i>p</i>	<i>e^B</i>
Right-handed	0.10	0.04	7.03	1	.008	1.11
Non-right-handed	−0.21	0.15	2.01	1	.156	0.81

Table 3
Logistic Regression of Sexual Orientation on Number of Older Sisters and Hand Preference for All Participants

Predictor	<i>B</i>	<i>SE</i>	Wald statistic	<i>df</i>	<i>p</i>	<i>e^B</i>
Older sisters	0.03	0.07	0.17	1	.68	1.03
Handedness	0.01	0.07	0.04	1	.85	1.01
Handedness $\times$ Older Sisters	0.02	0.07	0.05	1	.82	1.01

presumed to underlie the FBO effect. A gene of the Rh system (e.g., *RHD*, *RHCE*) may be a good candidate for this type of dual effect, as these genes have been linked to both handedness and immune system functioning (see Hatfield, 2006, for a review). Gene variants of the Rh system underlie the maternal immune response associated with the phenomenon known as hemolytic disease of the newborn. Rh is a factor in the blood, and if a mother is absent for this factor (Rh $-$), she may develop an immune response to an Rh $+$ fetus she is carrying, often with deleterious effects on the developing fetus. Hemolytic disease of the newborn has been argued to be a good model for explaining the FBO effect because it entails a powerful maternal immune response against a fetus and it accumulates over succeeding pregnancies. The fact that Rh genes are linked to handedness also makes them intriguing candidates to explain the present interaction between handedness and FBO (see also Bogaert, 2007, for a review).

Another gene-based explanation concerns variants of the androgen receptor (*AR*) gene. Medland et al. (2005) recently found that non-right-handedness in men is associated with shorter variations (fewer repeats) of the *AR* gene. Shorter variations (i.e., fewer repeats) of the *AR* gene are usually associated with lower testosterone in men. This pattern of results supports theory by Witelson (1991; Witelson & Nowakowski, 1991), who suggested that high prenatal testosterone leads to neuronal and axonal loss in the corpus callosum and contributes to right-handedness and associated functional asymmetry in men. Lower levels of prenatal testosterone have also been argued to underlie homosexuality in men (e.g., Ellis & Ames, 1987). Thus, both same-sex attraction and increased non-right-handedness patterns may result from fewer repeats of the *AR* gene because of its association to lower levels of testosterone. However, the *AR* gene has not been linked to sexual orientation (Macke et al., 1993). Perhaps variations of the *AR* gene would be linked reliably to sexual orientation if the present interaction between handedness and older brothers was taken into account. Thus, homosexuality in men may be associated with fewer repeats of the *AR* gene but only in non-right-handed homosexual men. In contrast, more repeats of the *AR* gene (and higher testosterone) would be associated with right-handed gay men,

particularly those with older brothers. This latter pattern may occur because more repeats of the *AR* gene (i.e., in right-handers) may increase the vulnerability of a fetus to a mother's potential immune attack.

The above-mentioned vulnerability may occur in one of three ways. First, more repeats of the *AR* gene may be correlated with higher levels of male-specific proteins on the surface of brain cells, which have been hypothesized as the targets of an immune attack of the mother against male fetuses (see Blanchard, 2004). Thus, fetal testosterone itself is not likely to be the target of a mother's immune attack because steroid hormones are not typically antigenic, but higher levels of fetal testosterone may be associated with high levels of other male-oriented factors (e.g., male-specific proteins) in sexual differentiation. Second, more repeats of the *AR* gene raise the level of testosterone in utero, which may raise a mother's testosterone and/or other hormones (e.g., cortisol) during pregnancy. There is evidence, for example, for a relationship between maternal and fetal hormones (e.g., Gitau, Adams, Fisk, & Glover, 2005; Meulenberg, & Hofman, 1991). This surge in hormones may alter a mother's immune system (see Van Vollenhoven & McGuire, 1994, for a review of steroid hormones on immune system functioning), which in turn may increase the likelihood of her mounting an immune response against the fetus. Third, higher testosterone in utero may be associated with birth complications, and this may lead to an increased susceptibility of an immune attack by the mother because of, for example, a weakened placenta. None of these three possibilities has any direct support, but if one or more of these possibilities is correct, right-handed fetuses (via more repeats on the *AR* gene) may have increased vulnerability to a mother's potential immune attacks, and if these right-handed fetuses have older brothers, the effect becomes pronounced. Future research assessing possible candidate genes (including variants of the *AR* gene) associated with male homosexuality should include the assessment of participants' handedness and number of older brothers. It is interesting to note that if this speculation is correct, this may also explain why characteristics related to both high and low testosterone are associated with homosexuality in men. Research has indicated that gay men have, on average, more feminine gender role characteristics (e.g., Bailey & Zucker, 1995), but there is also evidence that at least some gay men may have some more masculine characteristics associated with high (rather than low) prenatal testosterone (e.g., Alias, 2004; Bogaert & Hershberger, 1999; McFadden & Champlin, 2000). These more masculine characteristics may reflect higher levels of testosterone in right-handed fetuses before the mother's immune attack affected their sexual orientation.

Blanchard et al. (2006) proposed a third explanation of this interaction, namely that the combination of factors underlying the

Table 4
Logistic Regression of Sexual Orientation on Number of Older Sisters, With Separate Analyses for Right-Handed and Non-Right-Handed Participants

Participants	<i>B</i>	<i>SE</i>	Wald statistic	<i>df</i>	<i>p</i>	<i>e^B</i>
Right-handed	0.01	0.05	0.08	1	.78	1.01
Non-right-handed	0.04	0.13	0.11	1	.74	1.04

Table 5
Sex Ratio of Older Siblings in Heterosexual and Homosexual, Right-Handed and Non-Right-Handed Men

Sample	Participants	Older brothers	Older sisters	Sibling-sex ratio	One-tailed <i>p</i>
Heterosexual					
Right-handed	2,868	1,730	1,601	108	.313
Non-right-handed	357	219	186	118	.162
Homosexual					
Right-handed	646	469	368	127	.005
Non-right-handed	84	38	47	81	.126

FBO effect and non-right-handedness may be teratogenic to a developing fetus. There is evidence that non-right-handedness is associated with some neurodevelopmental problems (e.g., Coren, 1993; Previc, 1996) and developmental instability (e.g., Yeo et al., 1993). There is also evidence that a high number of older brothers are related to developmental disorders in subsequent male siblings (e.g., Gualtieri & Hicks, 1985; Lalumière, Harris, & Rice, 1999; but see Benderlioglu & Nelson, 2004). Thus, these factors by themselves may permanently alter the developing fetus (including changing sexual orientation), but in combination, these factors may be particularly deleterious, causing miscarriage or severe and isolating developmental disorders (e.g., mental retardation). If so, a relatively few number of homosexual men with non-right-handedness and with older brothers may be available for research in surveys.

When first examined, the Kinsey database did not reveal a significant relationship between handedness and sexual orientation (Bogaert & Blanchard, 1996). This was a notable null finding amid a number of supportive studies (see Lalumière et al., 2000). The Kinsey data were collected in an era (primarily the 1930s and 1940s) when family size was larger than in modern times. In that era, participants were likely to have had a high number of older brothers relative to participants drawn from most modern Western samples. The converse is also likely true: Kinsey participants were less likely than modern samples to have had no older brothers. Perhaps it is not surprising, then, that an elevated (main) effect for non-right-handedness was not observed for homosexual men in the Kinsey data, as the handedness effect may be restricted to gay men with no older brothers and there are likely fewer of these men in these data relative to those in modern samples. It would be interesting to consider other notable failures to replicate a handedness effect in men in light of this interaction. Perhaps these samples may too have had relatively large family sizes and thus may have revealed a handedness effect only as part of a Handedness $\times$ FBO interaction.

Number of older brothers has been more consistently shown to correlate with sexual orientation in men than handedness. Numerous studies from different eras and different countries, including large national probability samples, have shown the effect (for a review, see Blanchard, 2004). However, there have been a few studies that have not shown this effect (e.g., Frisch & Hviid, 2006; cf., Blanchard, in press; Frisch & Hviid, in press). These null results may have occurred because of idiosyncratic issues related to each sample, but, given the apparent reliability of this interaction, an additional consideration is that an FBO effect, like a handedness effect, may have only been detectable within these

(nonsupportive) samples as a Handedness $\times$ FBO interaction. Family size (i.e., number of older brothers) is relevant here as well. In some modern samples with small average family sizes, a substantial majority of the participants are likely to have no older brothers, and, thus, an FBO effect may be unlikely to be detected and may only emerge subsumed within an interaction with handedness. Thus, researchers examining the FBO effect in the future should consider handedness as a potentially important moderator variable.

It is important to address how the measures of sexual orientation and handedness in this historically significant data base compiled by Kinsey and his colleagues may differ from modern surveys. The measures used to form homosexual and heterosexual groups were similar to many modern assessments of sexual orientation, using both fantasy-attraction measures and behavior (e.g., Bogaert, 2003). Thus, the measures of sexual orientation are likely comparable across time with many modern surveys. However, unlike most assessments of handedness in contemporary surveys, only one question with four responses was used in the Kinsey interview protocol. Thus, this is a limitation in the present study that should be considered. It is important to note, however, that such a single-item measure of handedness likely correlates well with modern day, multiple-item inventories (e.g., Bryden, 1977). Thus, there is likely no gross departure from current standards of handedness assessment. Also, some contemporary research still assesses hand preference with a single item, namely, "hand used for writing" (see Peters et al., 2006). It is also important to remember that less reliable measures are less (not more) likely to achieve significant effects, and, in consequence, the effects observed in this study may have been stronger if a better measure of handedness was used. One way to improve measurement in future studies is to assess extreme right-handedness, a variation from moderate right-handedness that likely shares a similar etiology to some forms of non-right-handedness (e.g., Kim, Yi, Son, & Kim, 2001; Yeo et al., 1993). Also, like non-right-handedness, extreme right-handedness was recently found to be elevated in homosexual men (Bogaert, 2007). Moreover, like non-right-handedness, extreme right-handedness' relationship to men's sexual orientation was moderated by older brothers, (i.e., in extreme right-handers, older brothers did not affect or decreased the odds of homosexuality; Bogaert, 2007). Thus, it is interesting to consider whether the interactive effects in the Kinsey data may have been even stronger if handedness had been assessed in a finer grained way, allowing for variation in extreme right-handedness.

References

- Alexander, J. E., & Sufka, K. J. (1993). Cerebral lateralization in homosexual males: A preliminary EEG investigation. *International Journal of Psychophysiology*, 15, 269–274.
- Alias, A. B. (2004). A role for 5-alpha-reductase activity in the development of male homosexuality? *Annals of the New York Academy of Sciences*, 1032, 237–244.
- Allen, L. S., Hines, M., Shryne, J. E., & Gorski, R. A. (1989). Two sexually dimorphic cell groups in the human brain. *Journal of Neuroscience*, 9, 497–506.
- Bailey, J. M., Dunne, M. P., & Martin, N. G. (2000). Genetic and environmental influences on sexual orientation and its correlates in an Australian twin sample. *Journal of Personality and Social Psychology*, 78, 524–536.
- Bailey, J. M., & Zucker, K. J. (1995). Childhood sex-typed behavior and sexual orientation: A conceptual analysis and quantitative review. *Developmental Psychology*, 31, 43–55.
- Benderlioglu, Z., & Nelson, R. J. (2004). Season of birth and fluctuating asymmetry. *American Journal of Biology*, 16, 298–310.
- Blanchard, R. (2004). Quantitative and theoretical analyses of the relation between older brothers and homosexuality in men. *Journal of Theoretical Biology*, 230, 173–187.
- Blanchard, R. (in press). Older-sibling and younger-sibling sex ratios in Frisch and Hviid's (2006) national cohort study of two million Danes. *Archives of Sexual Behavior*.
- Blanchard, R., & Bogaert, A. F. (1996a). Biodemographic comparisons of homosexual and heterosexual men in the Kinsey interview data. *Archives of Sexual Behavior*, 25, 551–579.
- Blanchard, R., & Bogaert, A. F. (1996b). Homosexuality in men and number of older brothers. *American Journal of Psychiatry*, 153, 27–31.
- Blanchard, R., Cantor, J. M., Bogaert, A. F., Breedlove, S. M., & Ellis, L. (2006). Interaction of fraternal birth order and handedness in the development of male homosexuality. *Hormones and Behavior*, 49, 405–414.
- Blanchard, R., & Klassen, P. (1997). H-Y antigen and homosexuality in men. *Journal of Theoretical Biology*, 185, 373–378.
- Blanchard, R., & Lippa, R. A. (2007). Birth order, sibling sex ratio, handedness, and sexual orientation of male and female participants in a BBC internet research project. *Archives of Sexual Behavior*, 36, 163–176.
- Blanchard, R., & Lippa, R. A. (in press). The sex ratio of older siblings in non-right-handed homosexual men. *Archives of Sexual Behavior*.
- Bogaert, A. F. (1997). Birth order and sexual orientation in women. *Behavioral Neuroscience*, 111, 1395–1397.
- Bogaert, A. F. (2003). Number of older brothers and sexual orientation: New tests and attraction/behavior distinction in two national probability samples. *Journal of Personality and Social Psychology*, 84, 644–652.
- Bogaert, A. F. (2006). Biological versus nonbiological older brothers and men's sexual orientation. *Proceedings of the National Academy of Sciences, USA*, 103, 10771–10774.
- Bogaert, A. F. (2007). Extreme right handedness, older brothers, and sexual orientation in men. *Neuropsychology*, 21, 141–148.
- Bogaert, A. F., & Blanchard, R. (1996). Handedness in homosexual and heterosexual men in the Kinsey interview data. *Archives of Sexual Behavior*, 25, 373–378.
- Bogaert, A. F., & Hershberger, S. (1999). The relation between sexual orientation and penile size. *Archives of Sexual Behavior*, 28, 213–221.
- Bryden, M. P. (1977). Measuring handedness with questionnaires. *Neuropsychologia*, 15, 617–624.
- Bryden, M. P., & Steenhuis, R. E. (1991). Issues in the assessment of handedness. In F. L. Kitterie (Ed.), *Cerebral laterality* (pp. 35–51). Hillsdale, NJ: Erlbaum.
- Byne, W., Tobet, S., Mattiace, L. A., Lasco, M. S., Kemether, E., Edgar, M. A., et al. (2001). The interstitial nuclei of the human anterior hypothalamus: an investigation of variation with sex, sexual orientation, and HIV status. *Hormones and Behavior*, 40, 86–92.
- Chahnazarian, A. (1988). Determinants of the sex ratio at birth: Review of recent literature. *Social Biology*, 35, 214–235.
- Coren, S. (1993). *The left-hander syndrome*. New York: Vintage.
- Ellis, L., & Ames, M. A. (1987). Neurohormonal functioning and sexual orientation: A theory of homosexuality-heterosexuality. *Psychological Bulletin*, 101, 233–258.
- Frisch, M., & Hviid, A. (2006). Childhood family correlates of heterosexual and homosexual marriages: A national cohort study of two million Danes. *Archives of Sexual Behavior*, 35, 533–547.
- Frisch, M., & Hviid, A. (in press). The authors reply to commentary by Dr. R. Blanchard: "Older-sibling and younger-sibling sex ratios in Frisch and Hviid's (2006) national cohort study of two million Danes." *Archives of Sexual Behavior*.
- Gualtieri, T., & Hicks, R. E. (1985). An immunoreactive theory of selective male affliction. *Behavioral Brain Sciences*, 8, 427–441.
- Gebhard, P. H., & Johnson, A. B. (1979). *The Kinsey data: Marginal tabulations of the 1938–1963 interviews conducted by the Institute for Sex Research*. Philadelphia: Saunders.
- Gitau, R., Adams, D., Fisk, N. M., & Glover, V. (2005). Fetal plasma testosterone correlates positively with cortisol. *Archives of Disease in Childhood Fetal & Neonatal Edition*, 90, 166–169.
- Grady, K. L., Phoenix, C. H., & Young, W. C. (1965). Role of the developing rat testis in differentiation of the neural tissues mediating mating behavior. *Journal of Comparative and Physiological Psychology*, 59, 176–182.
- Hamer, D. H., Hu, S., Magnusson, V. L., Hu, N., & Pattatucci, A. M. L. (1993, July 16). A linkage between DNA markers on the X chromosome and male sexual orientation. *Science*, 261, 321–327.
- Hampson, E., Rovet, J. F., & Altmann, D. (1998). Spatial reasoning in children with congenital adrenal hyperplasia due to 21-hydroxylase deficiency. *Developmental Neuropsychology*, 14, 299–320.
- Hatfield, J. S. (2006). The genetic basis of hair whorl, handedness, and other phenotypes. *Medical Hypotheses*, 66, 708–714.
- Hepper, P. G., Shahidullah, S., & White, R. (1991). Handedness in the human fetus. *Neuropsychologia*, 36, 531–534.
- Hepper, P. G., Wells, D. L., & Lynch, C. (2005). Prenatal thumb sucking is related to postnatal handedness. *Neuropsychologia*, 43, 313–315.
- Hu, S., Pattatucci, M. L., Patterson, C., Li, L., Fulker, D. W., Cherny, S. S., et al. (1995). Linkage between sexual orientation and chromosome Xq28 in males but not in females. *Nature Genetics*, 11, 248–256.
- James, W. H. (1987). The human sex ratio: Part 1. A review of the literature. *Human Biology*, 59, 721–752.
- Kim, H., Yi, S., Son, E. L., & Kim, J. (2001). Evidence for the pathological right handedness hypothesis. *Neuropsychology*, 15, 510–515.
- Kinsey, A. C., Pomeroy, W. B., & Martin, C. E. (1948). *Sexual behavior in the human male*. Philadelphia: W. B. Saunders.
- Lalumière, M. L., Blanchard, R., & Zucker, K. J. (2000). Sexual orientation and handedness in men and women: A meta-analysis. *Psychological Bulletin*, 126, 575–592.
- Lalumière, M. L., Harris, G. T., & Rice, M. E. (1999). Birth order and fluctuating asymmetry: A first look. *Proceedings of the Royal Society of London*, 266, 2351–2354.
- LeVay, S. (1991, November 1). A difference in hypothalamic structure between heterosexual and homosexual men. *Science*, 253, 1034–1037.
- Macke, J. P., Hu, N., Hu, S., Bailey, M., King, V. L., Brown, T., et al. (1993). Sequence variation in the androgen receptor gene is not a common determinant of male sexual orientation. *American Journal of Human Genetics*, 53, 844–852.
- McCormick, C. M., & Witelson, S. F. (1991). A cognitive profile of homosexual men compared to heterosexual men and women. *Psychoneuroendocrinology*, 15, 69–76.
- McFadden, D., & Champlin, C. A. (2000). Comparison of auditory evoked

- potentials in heterosexual, homosexual, and bisexual males and females. *Journal of the Association for Research in Otolaryngology*, 1, 89–99.
- Medland, S. E., Duffy, D. L., Spurdle, A. B., Wright, M. J., Geffen, G. M., Montgomery, G. W., & Martin, N. G. (2005). Opposite effects of androgen receptor CAG repeat length on increased risk of left-handedness in males and females. *Behavior Genetics*, 35, 735–744.
- Meulenberg, P. M., & Hofman, J. A. (1991). Maternal testosterone and fetal sex. *Journal of Steroid Biochemistry and Molecular Biology*, 39, 51–54.
- Mustanski, B. S., Dupree, M. G., Nievergelt, C. M., Bocklandt, S., Schork, N. J., & Hamer, D. H. (2005). A genomewide scan of male sexual orientation. *Human Genetics*, 116, 272–278.
- Peters, M., Reimers, S., & Manning, J. T. (2006). Hand preference for writing and associations with selected demographic and behavioral variables in 255,100 subjects: The BBC internet study. *Brain and Cognition*, 62, 177–189.
- Previc, F. H. (1996). Nonright-handedness, central nervous system and related pathology, and its lateralization: A reformulation and synthesis. *Developmental Neuropsychology*, 12, 443–515.
- Rhees, R. W., Shryne, J. E., & Gorski, R. A. (1990). Termination of the hormone-sensitive period for differentiation of the sexually dimorphic nucleus of the preoptic area in male and female rats. *Brain Research: Developmental Brain Research*, 52, 17–23.
- Rice, G., Anderson, C., Risch, N., & Ebers, G. (1999, April 23). Male homosexuality: Absence of linkage to microsatellite markers at Xq28. *Science*, 284, 665–667.
- Swaab, D. F., & Hofman, M. A. (1990). An enlarged suprachiasmatic nucleus in homosexual men. *Brain Research*, 537, 141–148.
- Van Vollenhoven, R. F., & McGuire, J. L. (1994). Estrogen, progesterone, and testosterone: Can they be used to treat autoimmune diseases? *Cleveland Clinic Journal of Medicine*, 61, 276–284.
- Whitehead, N. E. (in press). An antibody antibody? Re-examination of the maternal immune hypothesis. *Journal of Biosocial Science*.
- Williams, T. J., Pepitone, M. E., Christensen, S. E., Cooke, B. M., Huberman, A. D., Breedlove, N. J., et al. (2000, March 30). Finger-length ratios and sexual orientation. *Nature*, 404, 455–456.
- Wilson, G., & Rahman, Q. (2005). *Born gay*. London: Peter Owen Publishers.
- Witelson, S. F. (1991). Neural sexual mosaicism: Sexual differentiation of the human temporo-parietal region for functional asymmetry. *Psychoneuroendocrinology*, 16, 131–153.
- Witelson, S. F., & Nowakowski, R. S. (1991). Left out axons make men right: A hypothesis for the origin of handedness and functional asymmetry. *Neuropsychologia*, 29, 327–333.
- Yeo, R. A., Gangestad, S. W., & Daniel, W. F. (1993). Hand preference and developmental instability. *Psychobiology*, 21, 161–168.

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